

Heat: An Agent of Change

Atoms and Molecules in Motion

TEACHER GUIDE

BACKGROUND INFORMATION

Everything in the universe is either matter or energy. All matter is made of combinations of about one hundred building blocks, the chemical elements on the periodic table. If these elements are broken down even further, we find that they are made of the same pieces. Scientists have named these pieces *protons*, *neutrons*, and *electrons*. The difference among the elements on the periodic table is simply the number of these particles that make up the various atoms. For example, chlorine, with 17 protons and electrons, is a deadly poisonous, greenish gas. Sodium, with 11 protons and electrons, is a metal that reacts so violently with water that it must be stored in a jar of oil so that it doesn't make contact with the water vapor in the air. Small differences in atomic structure make large differences in the properties of the atoms.

Two or more atoms bonded together make molecules. Two hydrogen atoms and one oxygen atom bonded together form water and water vapor and ice! How can the same combination of atoms form three different things?

Matter commonly exists on earth in three forms: solid, liquid, and gas. These three forms are called the **three states of matter**. Water is unusual because it can be readily found on Earth in all three states. Other matter is usually found in only one form at ordinary earth temperatures.

The main difference between material in the solid state, the liquid state, and the gas state is how fast its molecules are moving. As a solid, the molecules are tightly packed and cannot move very much. As a liquid, the molecules have more space and can move about more. Gas molecules are moving very fast and are even farther apart.

In this activity, students will physically experience the molecular proximity of solids, liquids, and gases. This activity can be quite effective if you guide the students in their thinking. It is important that students experience this activity rather than just listen to someone explain the scientific facts. Middle school students are still operating at the concrete operational stage and need the physical, concrete experience to assist the construction of their understanding of states of matter.

This activity allows you to address several misconceptions. The first is that temperature determines states of matter. Remember, each material has its own **heat of vaporization**, the amount of heat it takes to change a substance from a liquid to a gas. When you heat water on a stove in a kettle, the water will turn to vapor before the metal in the kettle melts. Heat (or the absence thereof) is necessary for a change of state. **Temperature** is a measurement of the presence or absence of heat.

Another misconception is that gases contain fewer molecules than do liquids or solids. Actually, it is the density (mass/unit volume), not the number of molecules that determines the state. That is why it is important to use the same number of students for all three parts of this activity.



Water is an anomalous material. Although it is obvious that water *vapor* (not *steam*—which is tiny liquid drops of water suspended in air) expands from its liquid volume, it may not be as obvious, and is definitely not the expected result, that ice also expands from its liquid volume. If you have ever filled ice cube trays right to the rim, you may have noted that the resulting cubes stick up over the top of the tray. The expansion of liquid water into ice allows ice to float. This unique property of water is thought to be a factor that allows life to exist on our planet.

STANDARDS ADDRESSED

Grades 5–8

Physical Science: [Transfer of energy](#)

Grades 9–12

Physical Science: [Conservation of energy and the increase in disorder](#)

MATERIALS NEEDED

Floor space for student simulation

Masking tape

(Optional)

Copies of Student Text: “Atoms and Molecules in Motion: States of Matter”

Student copies of: “Diagramming Atoms and Molecules in Motion” handout

An overhead transparency of: “Diagramming Atoms and Molecules in Motion” handout

PROCEDURE

Mark off a square on the floor that is 5 feet by 5 feet. Circumscribe a square of 8 feet by 8 feet. Stand 20 to 25 students in the 5 x 5 square equidistant to each other. They should be pretty close together. In fact, if they are touching shoulders that is fine.

Ask:

1. If you had to be this close to other students all of the time, how much personal space would you have?
2. If you wanted to move, would you bump someone?
3. If the person you bumped moved, would that person bump someone else?

Appoint one person to move so that another student is bumped.

Now have the first person move more so that the student who is bumped bumps into another student.

Ask:

4. What do you predict would happen if everyone were moving at the same time? Try it very carefully.
5. What do you think would happen if you were spread out more and someone moved?

Tell the students to move to the 8 x 8 square. Can they move farther without hitting other students? Does it take more energy to bump into someone else?

Now spread the students out so they are equidistant from each other taking up the space of the whole room.

6. What are the chances of bumping into each other now? Move around and see if you can move without hitting very many people. Was it hard to do?

Ask:

7. During this exercise, what were the variables?
Answer: number of students and space occupied
8. What changed?
Answer: space
9. What remained constant?
Answer: number of students

Say:

10. You have just illustrated the three stages of matter. Think back to when you were very close together.

Ask the students to return to this configuration.

11. Describe the characteristics of this state of matter.
Answer: molecules close together; not much can get between the molecules; hard to get through.
12. If I tried to walk through this object, could I?
Answer: no.
13. Can you think of an object that it is hard to get through or put things through?
Students should think of solid objects. Provide them with the term *solid* if they do not mention it independently.

Ask students to return to the second configuration.

Ask students to imagine that you are a different kind of molecule than they are. Then walk through the students. Make a wiggly path through them. Stay in one place for a minute and then move on. Illustrate that there are larger spaces within but there still isn't a lot of room. (You have illustrated what happens when salt dissolves in water. If you take away the water through evaporation, only the salt crystals are left.)

Say:

14. Describe the difference between this material and the material you labeled a solid.
Answer: more room between molecules; things can get through but the object stays basically the same.
15. Can you think of a substance that you can put your hand through but can return to the same shape it had before your hand was there? (Students may need an example. Have a glass of water available to show them what happens to the water when you put your hand in it then take it out.)
Answer: liquid or gas substances.
16. What do we call this state of matter?
Answer: liquid or gas

Once again, spread students out to take up the total space in the room.

17. What state of matter do you think this is?
Answer: gas
18. What are the characteristics of a gas that we can show by our placement in the room?
Answer: molecules far apart; more freedom of movement without collisions

Ask the class to return to their seats.

Say:

19. Molecules actually move in more ways than you illustrated. They vibrate (jiggle), rotate (spin), and translate (move from place to place). Molecules in all substances move all of the time. Can you predict the speed of relative

Alternate Strategies Brief

Depending on your students' abilities, you may need to enhance the background obtained through use of notes, handouts, or referral to textual material about matter and energy contained in the accompanying resource listed in the materials section of this guide.

At the middle school level, this information about the invisible world of the atom is often presented as a story which we ask them to accept without much ready evidence. Since so many middle school students have not had science experience at the concrete operational level, they are poorly equipped to work at an abstract level. However, in the activities in this module about heat, students can begin to see evidence that supports the abstract information you are sharing with them.

Students may be uncomfortable thinking about things they cannot see. They should be reminded that the scientists who first developed these theories couldn't see atoms or molecules either. Although they may not have acted out the states of matter with fellow scientists, they definitely engaged in imagination exercises similar to those presented here.

After checking for student understanding, give the students copies of the handout, "Diagramming Atoms and Molecules in Motion." They will take notes on the first two descriptions as you present on the overhead. Emphasize the spacing of the particles, rather than the number. Say, "In liquids the molecules are farther apart," rather than, "In liquids there are fewer molecules."

"Diagramming Atoms and Molecules in Motion" may be used as a formative assessment. See Assessment Options.

movement of molecules in each of these three states of matter? If you were very close to each other, could you move rapidly? What if you had a lot of room between you? What would be your chance of being able to rotate, vibrate, and translate?

20. How would you explain the difference between the speed of movement of the molecules in a substance as a solid and as a liquid?

Expect an answer like: the fact that liquids flow illustrates the molecules moving over each other more easily than would be possible in solid form.

Say:

In your laboratory notebook, fill in the chart to show your understanding of the structure of the three states of matter. Define solid, liquids, and gases and give an example of each that we did not talk about in class.

ADDITIONAL LEARNING OPPORTUNITIES

1. Use an alternate art form to communicate explanations for the three states of matter.
2. Examine the manner in which the concept of states of matter is explained in three different textbooks. Determine which one makes the most sense to you. Explain your choice.
3. Assign the Student Text, "Atoms and Molecules in Motion: States of Matter," as additional reading.

ASSESSMENT OPTION

Score the students' work on completing the handout, "Diagramming Atoms and Molecules in Motion."

RESOURCES

<http://jersey.uoregon.edu/vlab/Thermodynamics/index.html>

This site is a virtual thermodynamics experiment in which two containers of gas are connected by a membrane that can be made permeable or impermeable. The temperature of both containers is independently variable. Observing the motion of the molecules inside both containers under different conditions is a wonderful learning opportunity. However, there are no printed directions at this site. The teacher will need to provide some for student use.